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13. ABSTRACT (Maximum 200 words) We have constructed a testbed consisting of 4 mobile vehicles (with 4 additional vehicles vehicles being completed), each with embedded computing and communications capability for use in testing new approaches for command and control across dynamic networks. The system is being used or is planned to be used for testing of a variety of communications-related technologies, including distributed command and control algorithms, dynamically reconfigurable network topologies, source coding for real-time transmission of data in lossy environments, and multi-network communications. A unique feature of the testbed is the use of vehicles that have second order dynamics. Requiring real-time feedback algorithms to stabilize the system while performing cooperative tasks. The testbed was constructed in the Caltech Vehicles Laboratory and consists of individual vehicles with PC-based computation and controls, and multiple communications devices (802.11 wireless Ethernet, Bluetooth, and infrared). The vehicles are freely moving, wheeled platforms propelled by high performance dotted fairs. The room contains an access points for an 802.11 network, overhead visual sensing (to allow emulation of CI'S signal processing), a centralized computer for emulating certain distributed computations, and network gateways to control and manipulate communications traffic.			
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A Multi-Vehicle, Wireless Testbed for Networked Control, Communications, and Computing

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Final Report

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1 Background and Objectives

The goal of this DURIP project was to build a testbed for use in testing new approaches for command and control across dynamic networks. The testbed is designed to be useful for research in control, communications, and computing, with special emphasis on the integration of these research areas. The testbed is to be used for a variety of ongoing DoD projects.

2 Accomplishments

We have constructed a testbed consisting of 4 mobile vehicles (with 4 additional vehicles vehicles being completed), each with embedded computing and communications capability for use in testing new approaches for command and control across dynamic networks. The system is being used or is planned to be used for testing of a variety of communications-related technologies, including distributed command and control algorithms, dynamically reconfigurable network topologies, source coding for real-time transmission of data in lossy environments, and multi-network communications. A unique feature of the testbed is the use of vehicles that have second order dynamics, requiring real-time feedback algorithms to stabilize the system while performing cooperative tasks.

The testbed was constructed in the Caltech Vehicles Laboratory and consists of individual vehicles with PC-based computation and controls, and multiple communications devices (802.11 wireless Ethernet, Bluetooth, and infrared). The vehicles are freely moving, wheeled platforms propelled by high performance ducted fans. The room contains an access points for an 802.11 network, overhead visual sensing (to allow emulation of GPS signal processing), a centralized computer for emulating certain distributed computations, and network gateways to control and manipulate communications traffic.

An overview of the testbed is shown in Figure 1. The testbed consists of up to 8 vehicles operating on a flat floor, with four overhead cameras used to provide visual information. Communications is accomplished using wireless Ethernet (802.11b).

The original project plan called for one feature that has not yet been implemented. We originally intended to use Bluetooth for vehicle to vehicle communications, but the available hardware does not yet allow modulation of the transmitting power levels. As a consequence, it is not possible to

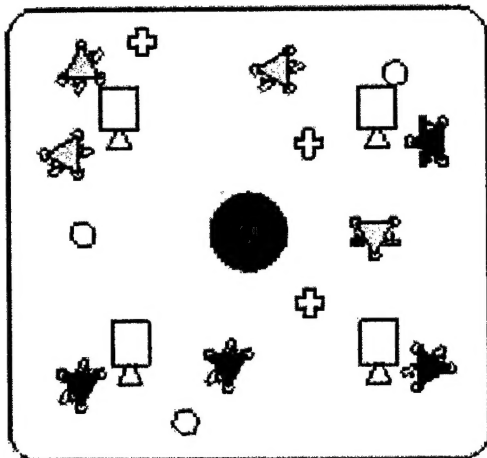


Figure 1: Overview of the Caltech multi-vehicles testbed: (a) schematic of the testbed architecture and (b) photograph of the testbed work area

get the limited communications range that we are interested in exploring at the present time. We have done prototype Bluetooth development and plan to implement Bluetooth communications at a later date, when the hardware is capable of power modulation.

A view of one of the individual vehicles is shown in Figure 2a. The vehicle consists of a base supported by ball castors, a laptop, two ducted fans, batteries and control electronics, and a patterned cover that identifies the vehicle to the vision system. Closed loop control of the vehicle, using feedback through the vision system and an onboard linear controller, is shown in Figure 2b.

The testbed is described in more detail in an upcoming conference paper [1], available from the PI's web page. The testbed is currently being used as a demonstration platform for an AFOSR project at Caltech on communications and control, a MURI with UCLA, MIT and Cornell on cooperative control, the DARPA Software Enabled Control (SEC) program and the DARPA Mixed Initiative Control of Automa-teams (MICA) program.

3 Personnel Supported

No research students were supported under this grant. Undergraduates were hired to perform the majority of the construction associated with the project.

References

- [1] Lars Cremean, William Dunbar, David van Gogh, Jason Hickey, Eric Klavins, Jason Meltzer, and Richard M. Murray. The caltech multi-vehicle wireless testbed. In *Proc. IEEE Control and Decision Conference*, 2002. To appear.

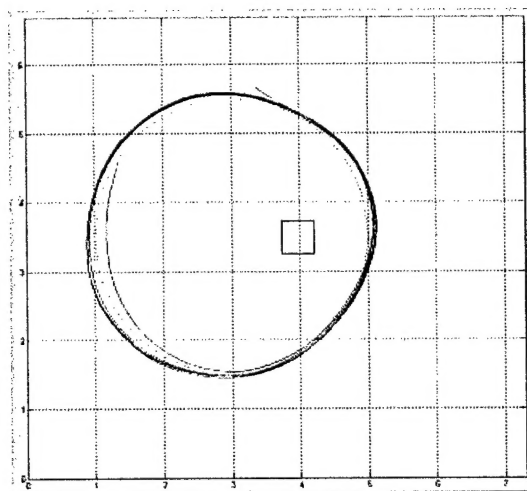
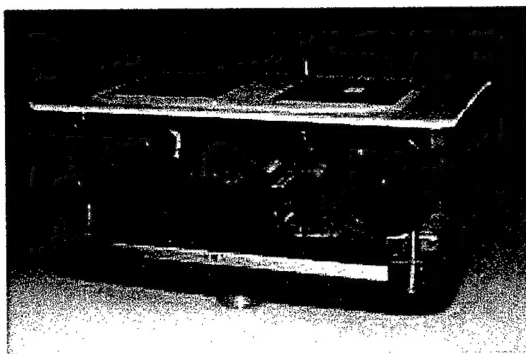


Figure 2: Individual vehicle from the multi-vehicle testbed: (a) isoperimetric view and (b) experimental results for tracking a circle.